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(54) Title: METHODS FOR TREATING A NEUROLOGICAL DISEASE BY DETERMINING BCHE GENOTYPE

(57) Abstract

Disclosed herein is a method for treating a patient with a neurological disease by determining a patient's BCHE allele status.

Ex 1
fig 3

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METHODS FOR TREATING A NEUROLOGICAL DISEASE BY DETERMINING BCHE GENOTYPE

Background of the Invention

In general, the invention relates to methods for treating a neurological disease.

Neurological diseases, for example, Alzheimer's disease, provide a unique series of complications for clinicians, patients, and care givers; the diseases often progress rapidly and disrupt a vast number of major life functions. The progressive nature of these diseases makes the passage of time a crucial issue in the treatment process. Treatment choices for neurological diseases, particularly those affecting cognitive function, can be complicated by the fact that it often takes a significant period of treatment to determine if a given therapy is effective. Accordingly, treatment with the most effective drug or drugs is often delayed while the disease continues to progress. A method that would allow one to predict which patients will respond to a specific therapy would provide physical and psychological benefits. As healthcare becomes increasingly inaccessible, the ability to allocate healthcare resources effectively also becomes more important.

Summary of the Invention

The present invention provides a method for treating a patient at risk for a neurological disease, or diagnosed with a neurological disease. The methods include identifying such a patient and determining the patient's BCHE allele status. The invention provides a method for using the patient's BCHE allele status to determine a treatment protocol which includes a prediction of the efficacy of a therapy for the treatment of a neurological disease. In a related aspect, the invention features a treatment protocol that provides a prediction of patient outcome.

In a another related aspect, the invention provides a method for identifying a patient for participation in a clinical trial of a therapy for the treatment of a

neurological disease. The method involves characterizing a patient with a disease risk and determining the patient's BCHE allele status. In yet another related aspect, the method further involves determining the patient's BCHE allele status and selecting those patients having at least one wild type BCHE allele, preferably having two wild type BCHE alleles, as candidates likely to respond to a therapy for the treatment of a neurological disease. In a preferred embodiment, the treatment protocol involves a comparison of the BCHE allele status of a patient with a control population and a responder population. This comparison allows for a statistical calculation of a patient's likelihood of responding to a therapy.

In preferred embodiments of two of the above aspects, the prediction of drug efficacy involves cholinomimetic therapies, preferably tacrine, or non-cholinomimetic therapies, preferably a vasopressinergic drug that will be effective in patients with the genotype of a least one non-BCHE-K allele, and preferably two non-BCHE-K alleles. In a preferred embodiment, the invention provides a treatment protocol that utilizes one of the following therapies for a neurological disease: probucol, a monoamine oxidase inhibitor, muscarinic agonist, neurotrophic factor, noradrenergic factor, antioxidant, anti-inflammatory, corticotrophin-releasing hormone (CRH), somatostatin, substance P, neuropeptide Y, or thyrotrophin-releasing hormone (TRH).

In a particular application of the invention, all of the above aspects feature a determination of the BCHE allele status of the patient, where a determination of the patient's BCHE-K allele status as being heterozygous or homozygous, is predictive of the patient having a poor response to a therapy for a neurological disease. In a preferred embodiment, the above methods are used for treating a neurological disease such as Alzheimer's disease, neurofibromatosis, Huntington's disease, depression, amyotrophic lateral sclerosis, multiple sclerosis, stroke, Parkinson's disease, or multi-infarct dementia. In another preferred embodiment, the invention is suitable for treating a patient with a non-AD neurological disease.

In another aspect, the invention provides a method for treating a patient at risk

for a non-AD neurological disease by a) identifying a patient with a risk, b) determining the BCHE allele status of the patient, and c) converting the data obtained in step b) into a treatment protocol that includes a comparison of the BCHE allele status with the allele frequency of a control population. This comparison allows for a statistical calculation of the patient's risk for having a non-AD neurological disease. In preferred embodiments, the method provides a treatment protocol that predicts a patient being heterozygous or homozygous for the BCHE-K allele to respond poorly to a cholinomimetic (e.g., tacrine) or specific non-cholinomimetic (e.g., vasopressinergics) therapy for a neurological disease, and a patient who is wild type BCHE homozygous, to respond favorably to the therapy.

In a related aspect, the invention provides treating a patient at risk for or diagnosed with a neurological disease using the above method, and conducting an additional step c) which involves determining the apoE allele load status of the patient. This method further involves converting the data obtained in steps b) and c) into a treatment protocol that includes a comparison of the allele status of these steps with the allele frequency of a control population. This affords a statistical calculation of the patient's risk for having a neurological disease. In a preferred embodiment, the method is useful for treating a neurological disease such as Alzheimer's disease, neurofibromatosis, Huntington's disease, depression, amyotrophic lateral sclerosis, multiple sclerosis, stroke, Parkinson's disease, or multi-infarct dementia. In addition, in related embodiments, the methods provide a treatment protocol that predicts a patient to be at high risk for a neurological disease and responding poorly to a cholinomimetic or particular non-cholinomimetic therapy (e.g., vasopressinergics) if the patient is determined to have both an apoE4 allele and a BCHE-K allele. Such patients are preferably given an alternative therapy.

The invention also provides a method for improving the efficacy of a therapy for the treatment of neurological diseases. The method includes the step of comparing the relative efficacy of the therapy in patients having different BCHE alleles.

Preferably, administration of the drug is preferentially provided to those patients with a BCHE allele type associated with increased efficacy. In a preferred embodiment, the alleles of BCHE used are wild type BCHE and BCHE associated with reduced biological activity. Most preferably the allele associated with reduced biological activity is BCHE-K.

As used herein, by "therapy for the treatment of a neurological disease" is meant any therapy suitable for treating a neurological disease. A suitable therapy can be a pharmacological agent or drug that may enhance cognitive function, motor function, or neuronal activity of the central nervous system, peripheral nervous system, or inhibit the further deterioration of any of these faculties.

By "cholinomimetic therapy" is meant any drug that mimics the function of acetylcholine or enhances the activity of acetylcholine synthesizing cells. These drugs include, but are not limited to, inhibitors of acetylcholine degradation (acetylcholine esterase inhibitors such as tacrine), drugs that mimic acetylcholine structure and function, drugs that block acetylcholine uptake by neurons, and drugs that interact with pre-synaptic receptors to induce acetylcholine release from cholinergic neurons.

By "non-cholinomimetic vasopressinergic therapy" is meant a therapy that utilizes a vasopressinergic modulator such as, for example, S12024 (provided by Servier, Les Laboratoires Servier, 22 rue Garnier, 92200 Neuilly sur Seine, France).

By "non-AD neurological disease" is meant a disease other than Alzheimer's disease, which involves the neuronal cells of the nervous system. Specifically included are: prion diseases (e.g, Creutzfeldt-Jakob disease); pathologies of the developing brain (e.g., congenital defects in amino acid metabolism, such as argininosuccinicaciduria, cystathioninuria, histidinemia, homocystinuria, hyperammonemia, phenylketonuria, tyrosinemia, and fragile X syndrome); pathologies of the mature brain (e.g., neurofibromatosis, Huntington's disease, depression, amyotrophic lateral sclerosis, multiple sclerosis); conditions that strike in adulthood (e.g. Creutzfeldt-Jakob disease, Lewy body disease, Parkinson's disease,

Pick's disease); and other pathologies of the brain (e.g., brain mishaps, brain injury, coma, infections by various agents, dietary deficiencies, stroke, multi-infarct dementia, and cardiovascular accidents).

By "Alzheimer's Disease (AD)" is meant a pathology characterized by an early and extensive loss of entorhinal cortex neurons. AD patients may be identified by progressive and degenerative effects on the brain which are not attributable to other causes. Post-mortem, the disease may be diagnosed by the presence of amyloid plaques and fibrils.

By "drug efficacy" is meant the determination of an appropriate drug, drug dosage, administration schedule, and prediction of therapeutic utility.

By "apoE4 allele load" is meant the relative ratio of apoE2, 3, and 4 alleles in the patient's chromosomal DNA. The allele load may be determined by comparing the relative numbers of the patient's already known apoE allele types.

By "apoE4 allele" is meant a particular apoE isoform that can be distinguished from other apoE isoforms (e.g., apoE2 or apoE3) using the methods of the invention.

By "PCR, RT-PCR, or ligase chain reaction amplification" is meant subjecting a DNA sample to a Polymerase Chain Reaction step or ligase-mediated chain reaction step, or RNA to a RT-PCR step, such that, in the presence of appropriately designed primers, a nucleic acid fragment is synthesized or fails to be synthesized, thereby revealing the allele status of a patient. The nucleic acid may be further analyzed by DNA sequencing using techniques known in the art.

By "BCHE allele status" is meant a determination of the relative ratio of wild type butyrylcholinesterase alleles compared to an allelic variant that may encode a butyrylcholinesterase gene product of reduced catalytic activity. This may be accomplished by nucleic acid sequencing, RT-PCR, PCR, examination of the BChE protein, a determination of the BChE enzyme activity, or by other methods available to those skilled in the art.

By "BCHE-K allele (k-allele)" is meant a polymorphism of the

butyrylcholinesterase (BCHE) gene which involves a point mutation at nucleotide 1828 that changes amino acid residue 539 from alanine to threonine and can result in an enzyme with reduced catalytic activity.

By "treatment protocol" is meant a therapy plan for a patient using genetic and diagnostic data, including the patient's neurological diagnosis and BCHE and ApoE genotypes. The protocol enhances therapeutic options and clarifies prognoses. The treatment protocol may include an indication of whether or not the patient is likely to respond positively to a cholinomimetic or non-cholinomimetic therapy. The treatment protocol may also include an indication of appropriate drug dose, recovery time, age of disease onset, rehabilitation time, symptomology of attacks, and risk for future disease. A treatment protocol, including any of the above aspects, may also be formulated for asymptomatic and healthy subjects in order to forecast future disease risks and determine what preventive therapies should be considered or invoked in order to decrease these disease risks. The treatment protocol may include the use of a computer software program to analyze patient data.

By "patient at risk for a neurological disease" is meant a patient identified or diagnosed as having a neurological disease, or having a genetic predisposition or risk for acquiring a neurological disease using the methods of the invention and techniques available to those skilled in the art.

By "converting" is meant compiling genotype determinations to predict either prognosis, drug efficacy, or suitability of a patient for participating in clinical trials of a neurological disease therapeutic. For example, the genotype may be compiled with other patient parameters such as age, sex, disease diagnosis, and known allelic frequency of a representative control population. The converting step may provide a determination of the statistical probability of the patient having a particular disease risk, drug response, or patient outcome.

By "prediction of patient outcome" is meant a forecast of the patient's likely health status. This may include a prediction of the patient's response to therapy,

rehabilitation time, recovery time, cure rate, rate of disease progression, predisposition for future disease, or risk of having relapse.

By "therapy for the treatment of a neurological disease" is meant any pharmacological agent or drug with the property of healing, curing, or ameliorating any symptom or disease mechanism associated with a neurological disease.

By "responder population" is meant a patient or patients who respond favorably to a given therapy.

The present invention provides a number of advantages. For example, the methods described herein allow for use of a determination of a patient's BCHE genotype for the timely administration of the most suitable therapy for that particular patient.

Other features and advantages of the invention will be apparent from the following detailed description and from the claims.

Detailed Description of the Invention

The drawings will first be described.

Brief Description of the Drawings

Fig. 1 is a depiction of the cDNA sequence of the wild type human butyrylcholinesterase gene (BCHE; SEQ ID NO: 1).

Fig. 2 is a depiction of the cDNA sequence of the human butyrylcholinesterase K-allele (BCHE-K) with the single nucleotide polymorphism at base 1828 indicated in bold (SEQ ID NO: 2).

Fig. 3 is a depiction of the amino acid sequence of the wild type human butyrylcholinesterase protein (BCHE; SEQ ID NO: 3).

Fig. 4 is a depiction of the amino acid sequence of the human

butyrylcholinesterase-K protein (BCHE-K) with the single amino acid residue change, from an alanine (A) to a threonine (T), indicated in bold (SEQ ID NO: 4).

Fig. 5 is a graphical depiction of the impact the BCHE-K allele has on the efficacy of tacrine treatment in patents diagnosed with AD.

The invention described herein features methods for determining the appropriate therapy for a patient at risk for a neurological disease based on an analysis of the patient's BCHE allele status. Specifically, the presence of at least one BCHE-K allele indicates that a patient will respond poorly to cholinomimetic and non-cholinomimetic therapies such as vasopressinergics. In a preferred approach, the patient's BCHE-K allele status is rapidly diagnosed using a sensitive PCR assay and a treatment protocol is rendered. The invention also provides a method for forecasting patient outcome and the suitability of the patient for entering a clinical drug trial for the testing of a therapy for a neurological disease.

The findings described herein indicate the predictive value of the BCHE-K allele in treating patients at risk for a neurological disease such as Alzheimer's disease (AD). In addition, because the underlying mechanism influenced by the BCHE allele status is not disease-specific, the BCHE-allele status is suitable for making patient predictions for non-AD neurological diseases as well.

The following examples, which describe preferred techniques and experimental results, are provided for the purpose of illustrating the invention, and should not be construed as limiting.

EXAMPLE 1

Methods for Determining BCHE-K or ApoE4 Allele Status

As described above, the present invention provides a technique for efficiently treating a patient with a neurological disease risk based on their BCHE genotype.

The butyrylcholinesterase (BCHE) gene product is expressed in most human

tissues, but its precise metabolic function in the body is still unknown. We have found that the polymorphic gene variant BCHE-K, consisting of a point mutation at nucleotide 1828 (GCA to ACA) which changes alanine 539 to threonine and can result in reduced catalytic activity (see Figs. 1-4), has strong predictive value for determining if cholinomimetic (e.g., tacrine) or non-cholinomimetic (e.g., vasopressinergics) therapies will help a patient at risk for a neurological disease.

To demonstrate the effectiveness of the BCHE-K allele as a prognostic indicator in patients with a neurological disease risk, we determined the BCHE-K allele load in a large number of patients diagnosed with Alzheimer's disease. In addition, to determine if the BCHE-K polymorphism correlated with other markers associated with a neurological disease, we also genotyped these patients for the presence of the apoE4 allele and determined the predictive value of this marker when used separately or together with the BCHE-K allele status determination.

To obtain DNA for genotyping we isolated genomic DNA from whole blood according to the Gustincich method (Gustincich S., et al. *Biotechniques* 11, 298-300 (1991). This method allowed for the rapid extraction of high quality genomic DNA from whole human blood, or alternatively, directly from a patient's serum.

Genotyping was then performed by subjecting nucleic acid samples encoding the BCHE gene to a polymerase chain reaction (PCR) amplification step followed by another round of PCR amplification using a nested PCR protocol. These amplification reactions were conducted using a PCRExpress™ thermal cycler from Hybaid. The first round of PCR amplification was conducted for 30 cycles using reaction conditions that involved a denaturation step at 94°C for 30 seconds, a primer annealing step at 65°C for 30 seconds, and a primer extension step at 70°C for 90 seconds using the following oligonucleotides: 5'-CTG TAC TGT GTA GTT AGA GAA AAT GGC-3' (SEQ ID NO: 5); and 5'-TTT TTA CGA GTG GTA ATG AAA ATA CAC GTG-3' (SEQ ID NO: 6).

Next, a 1:100 dilution of the first reaction product was used for conducting the

subsequent nested PCR reaction. The nested PCR reaction was carried out for a total of 45 cycles using a denaturation step at 95°C for 30 seconds, a primer annealing step at 58°C for one minute, and primer extension step at 72°C for one minute using the following oligonucleotides: 5'-CTG TAC TGT GTA GTT AGA GAA AAT GGC-3' (SEQ ID NO: 5); and 5'-Biotin-CCA CAC AAC TTT CTT TCT TGC TAG TG-3' (SEQ ID NO: 7). The resultant amplified PCR reaction product was analyzed using 1% agarose gel electrophoresis (Bio-Rad™) and visualized by ethidium bromide staining. The determination of the genetic variance of the BCHE gene was then completed using DNA sequencing.

The DNA sequencing of the BCHE-K polymorphism was conducted using an automated DNA sequencer (ALFexpress™ by Amersham Pharmacia Biotech) according to the manufacturers instructions and using the following sequencing primer: 5'-CY5-GCC-TTT-TGT-ATT-CGA-AAT-TAT-TTT-TC-3' (SEQ ID NO: 8).

In addition to BCHE genotyping, we performed apoE genotyping as follows. Allele-specific primer extension of purified brain DNA using a modification of the method of Main et al. was employed using primers labeled D, E, F, G, and H (synthesized by Genosys Biotech (The Woodlands, TX)) comprising sequence provided in Main et al. (Main R.F. et al., *J. Lipid. Res.*, 32:183-187 (1991)). Reactions were carried out in a volume of 50 µL containing 1 µg of DNA; deoxyadenosine triphosphate, deoxycytidine triphosphate, deoxythymidine triphosphate and deoxyguanosine triphosphate, each 0.2 mmol/L; 10% dimethyl sulfoxide; 12.5 pmol of either primer D, E, F, or G; 25 pmol of primer H; and 10 µL of 10x PCR reaction buffer (Vector Biosystem, Toronto, ONT.). The DNA in the reaction mixture was first denatured for 10 min. at 96°C and then cooled to 4°C. One unit of Taq polymerase (Vector Biosystem, Toronto, ONT.) was then added to each sample. Each sample was reheated for 2 min. at 96°C and subjected to 30 cycles in a thermal cycler with each cycle consisting of a 10 sec. denaturation at 96°C, 30 sec. annealing at 58°C, and 1 min. extension at 65°C. The reaction products were

visualized using 1% agarose gel electrophoresis and ethidium bromide. The gels were then photographed and the banding profile was compared to known standards.

In addition to the above-mentioned methods, the methods provided in any of the pending applications (Serial Nos.08/727,637; 08/766,975; US97/22699; 60/059,908; 08/991,850) and following references (Brindle N. et al., *Hum. Mol. Genet.* 7:933-935 (1998); Singleton et al., *Hum Mol Genet* 7:937-939 (1998); Lehmann et al., *Hum. Mol. Genet.* 6:1933-1936 (1997); Richard et al., *Lancet* 349:539 (1997); and Gustincich S, et al., *Biotechniques* 11(3):298-300 (1998)) may also be used.

EXAMPLE 2

Use of the BCHE-K Allele as a Predictor of Non-Cholinomimetic Drug Efficacy

To demonstrate the effectiveness of the BCHE-K allele as a predictor of non-cholinomimetic drug efficacy in patients at risk for a neurological disease, we analyzed the genomic DNA and cognitive scores of the AD patient group of Richard et al. (*Lancet* 349:539 (1997)). In this study, 199 patients diagnosed with Alzheimer's disease were divided into two groups and one group (n=91) was administered a non-cholinomimetic therapy (the vasopressinergic drug, S12024, from Servier; administered at 100 mg per day) and the other group (n=108) was administered a placebo.

To quantitate changes in cognitive function during the clinical trial, patients were evaluated using the Mini Mental State Examination (MMSE) and a baseline score was determined for each patient prior to treatment. Following 12 weeks of drug or placebo treatment, both patient groups were re-evaluated using the same test. The difference in MMSE score results, before and after treatment, was determined for each patient in the study with a positive change in score indicating an improvement in cognitive ability and a negative change in score indicating a deterioration.

Butyrylcholinesterase genotyping was done as described in Example 1 and each

patient was categorized as either possessing at least one BCHE-K allele (k-allele) or lacking the k-allele. That is, patients were dichotomized as either k-allele or non-k-allele subjects and the predictive value of the k-allele on the response to drug as measured by a difference in MMSE score results was used to determine its pharmacogenetic influence.

When the total number of patients administered a placebo (n=108) versus the total number of patients administered the non-cholinomimetic therapy S12024 (n=91), were analyzed for an improvement in their MMSE score irrespective of their k-allele genotype, no statistically significant difference was observed between the two groups ($p>0.05$). Analyzed in this way, the data would suggest that the non-cholinomimetic vasopressinergic therapy was ineffective for improving Alzheimer's disease in these patients (Table 1).

However, when the treated group was stratified using the k-allele genotype, a statistically significant difference ($p<0.05$) in drug-mediated improvement was observed in the non-k-allele subgroup (n=30) as compared to the k-allele subgroup (n=61) (Table 2). The non-k-allele group had the highest MMSE score, indicating an improvement in cognitive ability, while the k-allele group had the lowest MMSE score, indicating a deterioration in cognitive ability. Thus, the k-allele genotyping distinguished two genetically different groups within the treatment group that responded differently to non-cholinomimetic therapy. Stated another way, the k-allele genotyping revealed that there was indeed a patient subgroup that can favorably respond to the non-cholinomimetic therapy S12024 for AD.

Sorting placebo treated patients by k-allele genotype did not resolve a statistically significant difference ($p>0.05$) between the k-allele subgroup (n=69) and the non-k-allele subgroup (n=39) (Table 1).

Tabl 1

Absence f BCHE Correlated Improvem nt (as measured by MMSE) in Patients Treated with a Placebo

	mean	median
total	-0.9	-1.0
non-k-allele	-1.1	-1.0
k-allele	-0.6	-1.0

Table 2

BCHE Correlated Improvement (as measured by MMSE) in Patients Treated with a Non-Cholinomimetic Drug

	mean	median
total	-0.1	0.0
non-k-allele	+0.3	0.0
K-allele	-1.0	-1.5

EXAMPLE 3

Dual BCHE-K, ApoE4 Genotyping to Predict Non-Cholinomimetic Drug Efficacy

Having determined that the cognitive ability of members of the non-k-allele AD subgroup would be predicted to improve when administered a vasopressinergic drug, we wanted to determine if other markers associated with AD, alone or in combination with BCHE, had a predictive value with this drug.

We further analyzed the AD patient scores and genotyping analysis of Richard et al. (*Lancet* 349:539 (1997)) supplemented with additional butyrylcholinesterase k-allele genotyping as provided herein. For our analysis, we evaluated patients using two tests, the MMSE and ADAS-Cog, which quantitate changes in cognitive function. For changes in MMSE results, we considered a score of zero or larger as a positive response and for a difference in ADAS-Cog results, we considered a score of zero or lower a positive response. Thus, each AD patient was categorized as either having a response or non-response to drug treatment.

First, we analyzed the relationship between an AD patient's response to a non-cholinomimetic therapy (S12024 from Servier; administered at a dose of 100 mg per day) as a function of apoE4 genotype and these results are presented in Table 3.

Table 3

Number of Patients Responding to Non-Cholinomimetic Drug Treatment as a Function of ApoE Genotype

	Response	Non-response
E4	40	23
Non-E4	15	13

Chi square (Yate's correction)=0.437 (p>0.5)
Odds ratio= 1.51

Our analysis showed that AD patients with an apoE4 allele, who are given a non-cholinomimetic therapy are only 1.5 times more likely to respond to therapy than non-apoE4 AD patients and this difference is not statistically significant. Thus, we concluded that the apoE4 genotype alone does not influence the response of AD patients to a non-cholinomimetic therapy.

Next, we analyzed AD patients responding to a placebo as a function of their apoE4 genotype (Table 4). Our results showed that an AD patient's apoE4 genotype does not influence their response to a placebo.

Table 4

Number of Patients Responding to Placebo Treatment as a Function of ApoE Genotype

	Response	Non-response
E4	29	37
Non-E4	20	22

Chi square (Yate's correction) = 0.031 (p>0.8)
Odds ratio=0.86

By contrast, when we genotyped AD patients responding to a non-

cholinomimetic vasopressinergic therapy for Alzheimer's disease, the absence of the k-allele was found to be a statistically significant predictor of a favorable drug response in the patient. Stated another way, the odds are that if a patient does not have a k-allele and is given the drug, they are three times more likely to respond to the drug than control patients having a k-allele (Table 5).

Table 5

Number of Patients Responding to Non-Cholinomimetic Drug Treatment as a Function of BCHE Genotype

	Response	Non-response
Non-k allele	42	19
k-allele	13	17

Chi square (Yates correction) = 4.46 ($p<0.035$)

Odds ratio=2.89

When a similar analysis was performed on patients responding or not responding to placebo as a function of their k-allele, no statistically significant correlation was observed (Table 6).

Table 6

Number of Patients Responding to Placebo as a Function of BCHE Genotype

	Response	Non-response
Non- k allele	34	35
k-allele	15	24

Chi square (Yates correction) = 0.78 ($p>0.35$)

Odds ratio=1.55

To summarize the predictive value of BCHE-K genotyping for determining the probability of a patient responding to therapy, the odds ratio of these data were calculated. The odds ratio of a patient with Alzheimer's disease responding to a non-cholinomimetic drug and having a non-k allele genotype is three fold over a k-allele

matched control (Table 7).

Tabl 7

Summary of Odds Ratio for a Patient Response to Drug as a Function of ApoE4 vs. BCHE

	placebo	treated
E4	p>0.8 O.R.=0.86	P>0.5 O.R.=1.51
Non k-allele	p>0.35 O.R.=1.53	P<0.035 O.R.=2.89

Similarly, AD patients who are apoE4 carriers and k-allele negative, are almost three times more likely to respond positively to a non-cholinomimetic therapy than a k-allele carrier (Tables 8 and 9).

Table 8

Number of Patients Responding to Drug as a Function of Having a ApoE4 and BCHE Genotype

	responder	non-responders
E4 positive and k minus	33	12
all others	22	24

Chi square (Yate's correction) = 5.2 (p<0.025)
Odds ratio=3

Table 9

Number of BCHE k Minus Patients Responding to Drug

	responder	non-responder
treated	42	19
placebo	34	35

Chi square (Yate's correction) = 4.33 (p<0.04)
Odds ratio=2.28

EXAMPLE 4

Use of the BCHE-K Allele as a Predictor of Cholinomimetic Drug Efficacy

In order to demonstrate that the BCHE-K allele is predictive of patient response

to other drugs outside the non-cholinomimetic drug class, we BCHE-genotyped AD patients being treated with the cholinomimetic drug tacrine.

We followed patients for 30 weeks of treatment with the cholinomimetic drug tacrine (Cognex® from Parke-Davis) using the MMSE test to quantitate changes in cognitive function. After 30 weeks of cholinomimetic drug treatment, the patient's MMSE score was compared to the patient's baseline MMSE score. We considered a patient with a positive MMSE value change as having a favorable response to the drug, and a patient having a zero or negative MMSE value change as not responding to the drug.

In Table 10, we present the number of patients responding or not responding to the cholinomimetic drug, tacrine, as a function of their BCHE-K genotype (see also Fig. 5). We observed that the number of non-k-allele patients responding positively to tacrine was three-fold higher than the number of non-k-allele positive patients who did not respond to tacrine. In the k-allele carrier group we observed virtually the same number of patients responding to drug as compared to patients not responding to drug.

Table 10

Number of Patients Responding to Tacrine as a Function of Having a BCHE Genotype

	Responders	Non-responders
Non K-allele	23	8
K-allele	10	7

To further determine how robust the BCHE-K polymorphism is as a predictor of a patient's treatment response, we calculated the odds ratio of being a responder with a non-k-allele. An odds ratio of 2.01 was calculated when taking the k-allele carrier status into account. Thus, we concluded that non-k-allele patients had a two-fold higher probability of responding well to a cholinomimetic therapy than k-allele patients. This conclusion is similar to the one we reached for non-k-allele patients

administered a non-cholinomimetic vasopressinergic therapy (Examples 2 and 3).

EXAMPLE 5

Use of the BCHE-K and ApoE4 Allele to Determine a Patient's Risk for Alzheimer's Disease

We have discovered that the combination of an apoE4 and BCHE-K allele contribute to define an individual's risk for the development of AD especially in patients between the ages of 60 and 75. To reach this conclusion, we compiled the apoE4 and BCHE-K genotypes for 224 AD patients and 97 age-matched healthy controls (Table 11) and analyzed the allelic frequency of these two genes in control patients versus patients with AD.

Table 11

Combined ApoE and BCHE Genotype Distribution

BCHE genotype

	wt				K-heterozygous				K-homozygous					
APOE	AD		Control		AD		Control		AD		Control		Total	
Alleles	n	%	n	%	n	%	n	%	n	%	n	%	AD	Control
2/2	0 (0)	0.00	0 (0)	0.00	0 (0)	0.00	0 (0)	0.00	0 (0)	0.00	0 (0)	0.00	0 (0)	0 (0)
2/3	3 (2)	0. 75	3 (1)	0. 50	0 (0)	0.00	3 (0)	0. 50	1 (0)	0. 25	0 (0)	0. 00	4 (2)	6 (1)
2/4	2 (1)	0. 29	2 (1)	1. 00	5 (3)	0. 71	0 (0)	0. 00	0 (0)	0. 00	0 (0)	0. 00	7 (4)	2 (1)
3/3	35 (22)	0. 70	34 (14)	0. 76	12 (8)	0. 24	10 (2)	0. 22	3 (3)	0. 06	1 (1)	0. 02	50 (33)	45 (17)
3/4	32 (20)	0. 52	14 (7)	0. 82	25 (19)	0. 41	3 (1)	0. 18	4 (3)	0. 06	0 (0)	0. 00	61 (42)	17 (8)
4/4	8 (5)	0. 62	0 (0)	0. 00	5 (3)	0. 38	0 (0)	0. 00	0 (0)	0. 00	0 (0)	0. 00	13 (8)	0 (0)
Total	80 (50)		53 (23)		47 (33)		16 (3)		8 (6)		1 (1)		135 (89)	70 (27)

When we calculated the allelic frequency of the apoE4 or BCHE-K allele in controls and patients with AD, we found that the BCHE-K allelic frequency in AD cases was 23% as compared to 13% in healthy age-matched controls (Controls A, Table 12). Similarly, the apoE4 allelic frequency was higher in patients with AD (35%) as compared to age-matched controls (14%) . For comparison, the apoE4 and BCHE-k allele frequency is provided for two other neurological diseases: multiple sclerosis (MS) and Parkinson's disease (PD).

Table 12

BCHE-K and Apo E4 Allele Frequencies in Study Group

	No. Of subjects	F:M ratio	Mean age (SD)	BCHE-K allele frequency	Apo E4 allele frequency
Controls (A) >60 years	70	0.56	74 (9.2)	0.13	0.14
Controls (B) >60 years	64	F only	72 (10. 2)	0.20	0.12
AD cases >60 years	135	1.14	78 (7.8)	0.23*	0.35**
PD cases	59	F only		0.20	0.11
MS cases	64	F only		0.16	0.12

* P<0.02 chi-square Yate's corr. (vs Controls A)
** P<0.0001 chi-square Yate's corr. (vs Controls A)

When we looked at the frequency of AD patients having both a BCHE-K allele and an apoE4 allele, as compared to age-matched controls, we observed that these alleles were over represented only in AD patients. In this patient group, 48% of the AD patients had both alleles as compared to 16% of the healthy age-matched controls (Table 13).

Tabl 13

Frequency of BCHE-K and ApoE4 Allele Both Occurring in Controls vs. AD Patients

Subjects	controls	cases	P (chi square Yates corr.)
All >60 years	3/70 (4%)	39/135 (29%)	<0.0001
All >75 years	1/27 (4%)	28/89 (31%)	<0.008
Apo E4 carrier > 60 years	3/19 (16%)	39/81 (48%)	0.021
Apo E4 carrier> 75 years	1/9 (11%)	28/54 (52%)	0.056*

* not significant

A similar conclusion can be drawn from an analysis of the odds ratios calculated for AD patients and age-matched controls as a function of being apoE4 carriers. In this comparison, the probability of a confirmed AD patient with a BCHE-K allele also having an apoE4 allele is two-fold higher over age-matched controls (Table 14).

Conversely, when these data are analyzed by calculating the odds ratio of a confirmed patient with an apoE4 allele as also having a BCHE-K allele, the odds are over two-fold higher compared to age-matched controls (Table 15).

Table 14

Odds Ratios of Confirmed AD for BCHE-K Alleles

Subjects	Cases	Controls	Odds ratio (alleles)	95% C.I.	Odds ratio (carriers)	95% C.I.
All>60 years	135	70	2.1	1.15-3.85	2.1	1.1-4.1
All>75 years	89	27	3.3	1.2-9.1	4.5	1.4-15
Apo E4 carriers >60 years	81	19	4.2	1.2-15	4.95	1.3-19
Apo E4 carriers >75 years	54	9	6.8*	0.8-55	8.6*	0.95-79

*not significant

Table 15

Odds Ratios of Confirmed AD for Apo E4 Alleles

Subjects	Cases	Controls	Odds ratio (alleles)	95% C.I.	Odds ratio (carriers)	95% C.I.
All>60 years	135	70	3.4	2.0-5.8	4.0	2.1-7.5
All>75 years	89	27	2.7	1.2-6.1	3.1	1.2-8.2
BCHE-K carriers >60 years	55	17	6.9	2.1-23	11.4	3.0-43
BCHE-K carriers >75 years	39	4	4.6*	0.3-64	7.6*	0.4-147

*not significant

In Table 16, we provide the odds ratios for AD subjects carrying at least one allele of apoE4 and BCHE-K as compared to control subjects who have neither allele. In subjects between 60 and 75 years of age who carry both an apoE4 and BCHE-K alleles, the odds ratio of having AD is 12.7 fold higher than age-matched controls. For subjects greater than 75 years of age, the odds ratio of having AD is 17.5 fold higher than age-matched controls. These data predict a strong correlation between the presence of these two alleles and being at risk for AD.

Table 16

Odds ratios of confirmed AD for BCHE-K alleles

Ap E4 carriers	BCHE-K carriers	Controls	Cases	Odds ratio	95% C.I.
All>60 years					
-	-	37	38	Reference	
-	+	14	16	1.1	not significant
+	-	16	42	2.6	1.2-5.8
+	+	3	39	12.7	4.1-39
All>75 years					
-	-	15	24	Reference	
-	+	3	11	2.3	not significant
+	-	8	26	2.0	not sign. (0.6-6.7)
+	+	1	28	17.5	2.8-108

In summary, we have discovered that determining an individuals's apoE4 and BCHE-K allele status is a useful tool in the prediction of an individual's risk for AD. Furthermore, our results demonstrate that prognostic forecasting can afford patients the ability to start prophylactic therapies before disease strikes. For example, the risk of AD can be calculated for asymptomatic, healthy individuals as young adults and well before the onset of measurable symptoms. Then, as the individual ages, preventive therapies can be invoked in order to prevent or lessen the progression of AD later in life.

Other Embodiments

The invention described herein provides a method for treating patients with a neurological disease risk by determining the patients' BCHE-K allele status and providing a forecast of the patients' ability to respond to a given drug treatment. In particular, the invention provides a method for determining, based on the presence or absence of the BCHE-K polymorphism, a patient's likely response to two major classes of drug therapies used in the treatment of neurological diseases (i.e., cholinomimetic and non-cholinomimetic). We conclude that, given the predictive value of the BCHE-K polymorphism across two different classes of drug, having different mechanisms of action, the BCHE-K polymorphism is likely to have a similar predictive value for other drugs acting through other pharmacological mechanisms. Thus, the methods of the invention may be used to determine a patient's response to other drugs including, without limitation, monoamine oxidase inhibitors, muscarinic agonists, neurotrophic factors, noradrenergic factors, antioxidants, and anti-inflammatories.

In addition, while determining the presence or absence of the butyrylcholinesterase K allele is a clear predictor for determining the efficacy of a drug in a given patient, other BCHE allelic variants of reduced catalytic activity are envisioned as predicting drug efficacy using the methods described herein. In

particular, the methods of the invention may be used to treat patients with any of the following known BCHE mutations (e.g., deletions (BCHE*FS4), missense mutations (BCHE*24 M, *1005, *250P, *267R, *330I, *365R, *418S, *515C), and nonsense mutations (BCHE*119STOP, *465STOP)).

In addition, while the methods described herein are preferably used for the treatment of human patients, non-human animals (e.g., pets and livestock) may also be treated using the methods of the invention.

All publications and patent applications mentioned in this specification are herein incorporated by reference to the same extent as if each independent publication or patent application was specifically and individually indicated to be incorporated by reference.

Other embodiments are within the claims.

What is claimed is:

Claims

1. A method for treating a patient at risk for a neurological disease, said method comprising:
   a) identifying said patient;
   b) determining the BCHE allele status of said patient; and
   determining the preferred therapy for the treatment of said neurological disease.

2. A method for treating a patient at risk for a neurological disease, said method comprising:
   a) identifying said patient;
   b) determining the BCHE allele status of said patient, said allele status indicating a prediction of patient outcome.

3. A method for characterizing a patient for participation in a clinical trial of a therapy for the treatment of a neurological disease, said method compromising:
   a) identifying a patient at risk for said disease;
   b) determining the BCHE allele status of said patient.

4. The method of claim 1 or 2, wherein said preferred therapy includes administering a cholinomimetic or non-cholinomimetic vasopressinergic therapy if said patient has at least one wild type BCHE allele.

5. The method of claim 4, wherein said patient has two wild type BCHE alleles.

6. The method of claim 3, wherein at least one wild type BCHE allele indicates a patient likely to respond to said therapy.

7. The method of claim 3, wherein said patient having at least two wild type BCHE alleles is preferentially selected for the trial of said therapy.

8. The method of claim 3, wherein said method further includes a comparison of the BCHE allele status in said patient with the BCHE allele status of a control population and a responder population, said comparison allowing for a statistical calculation of a diseased individual's likelihood of responding to said therapy.

9. The method of claim 1 or 3, wherein said therapy is a cholinomimetic therapy.

10. The method of claim 9, wherein said drug is tacrine.

11. The method of claim 1 or 3, wherein said drug is a non-cholinomimetic vasopressinergic drug.

12. The method of claim 1 or 3 ,wherein said therapy is probucol, a monoamine oxidase inhibitor, muscarinic agonist, neurotrophic factor, noradrenergic factor, antioxidant, anti-inflammatory, corticotrophin-releasing hormone (CRH), somatostatin, substance P, neuropeptide Y, or thyrotrophin-releasing hormone (TRH).

13. The method of claim 1, 2, or 3, wherein said BCHE allele status is heterozygous or homozygous for the BCHE-K allele, said BCHE-K allele status predicting a poor patient response to a therapy for a neurological disease.

14. The method of claim 1, 2, or 3, wherein said neurological disease is selected from the group consisting of Alzheimer's disease, neurofibromatosis,

Huntington's disease, depression, amyotrophic lateral sclerosis, multiple sclerosis, stroke, Parkinson's disease, and multi-infarct dementia.

15. The method of claim 1, 2, or 3, wherein said neurological disease is a non-AD neurological disease.

16. A method for treating a patient at risk for a non-AD neurological disease, said method comprising:

a) identifying said patient;

b) determining the BCHE allele status of said patient, said BCHE allele status indicating said patient's risk for having a non-AD neurological disease, the presence of a BCHE-K allele indicating an increased likelihood of said disease.

17. The method of claim 16, wherein said method further includes a comparison of the allele status in step b) with the BCHE allele frequency in a control population or predictions derived therefrom.

18. A method for treating a patient at risk for a neurological disease, said method comprising:

a) identifying said patient;

b) determining the BCHE allele status of said patient;

c) determining the apoE4 allele load status of said patient; and

d) converting the data obtained from steps b) and c) into a determination of said patient's risk for having a neurological disease.

19. The method of claim 18, wherein said treatment protocol includes a comparison of the allele status in steps b) and c) with the BCHE allele and apoE4 allele frequency in a control population.

20. The method claim 18, wherein said neurological disease is Alzheimer's disease.

21. The method claim 18, wherein said neurological disease is a non-AD neurological disease.

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```

Fig. 1

```
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Fig. 2

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Fig. 3

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Fig. 4

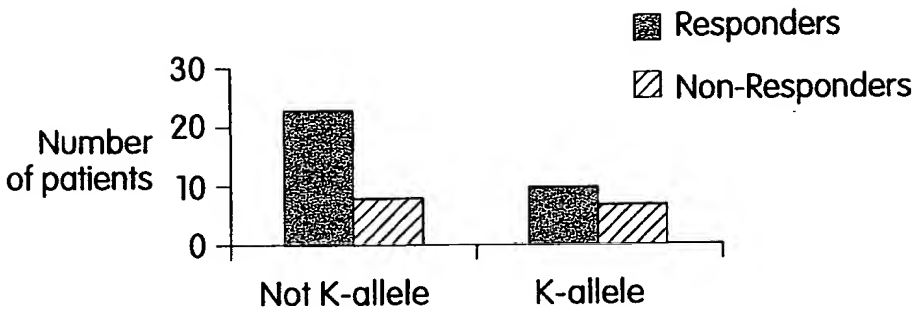
Responders
Non-Responders
Number of patients
30
20
10
0
Not K-allele
K-allele

Fig. 5